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VERBAL ESTIMATION OF DISTANCE IN A SIMULATED SPACE ENVIRONMENT

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SUMMARY

Preliminary work has indicated that when Ss are given no information other than the real size of the target, verbal estimates of distance over the 200 - 5000 ft. range tend to have a median error of about 55%, with errors on individual trials running as high as 1000%. Two experiments investigated possible ways of improving the accuracy of verbal judgments. Effects due to kind of stimulus sequence (random or sequential), distance range, and the presence of verbal anchors were examined. In the first experiment the limits of the distance range being used were shown and identified to the Ss before each set of 10 judgments of randomly chosen distances. The use of these "anchors" reduced the median error to about 15%. A second experiment investigated the effect of sequential presentation of distances. The effect of anchors was about the same, but there were also some adaptation effects stemming from the sequential order of stimulation.

INTRODUCTION

Recent developments in space exploration have made it clear that future missions will require more and more participation and responsibility on the part of human operators. Furthermore, even in those tasks in which primary dependence is placed upon mechanical devices for obtaining necessary observations and for making critical control decisions, it is necessary to determine the ultimate back-up capability of the human being in the event of equipment failure. It is important, therefore, that information be gathered concerning the fundamental capabilities of the astronaut to obtain observational data, to process these data and arrive at command decisions, and to execute the necessary control adjustments accomplishing the various tasks essential to the success of a mission in space.

There are a number of tasks involving visual perception which will have to be performed under conditions quite different from comparable tasks performed on or near the surface of the earth. These tasks involve detection, identification, tracking, distance judgment, and visual orientation. They will occur most prominently in the accomplishment of orbital rendezvous and planetary landing. The primary difficulty in the performance of such tasks in space derives from the fact that most human observers have had no experience with the properties of light in a vacuum.

The perceptual judgment which will be most affected by the absence of an atmosphere is that of judging distance. Binocular cues to distance judgment decrease rapidly in effectiveness as distance increases, and most monocular cues depend upon gradients which occur either in the atmosphere or in the physical "substrate" which is continuous between the observer and the distant object. Both of these kinds of cues will, of course, be absent in space, and the observer will generally be dependent upon only two cues, relative brightness and the size of the retinal image. The first of these, relative brightness, will seldom provide reliable information, since it will vary as a function of orientation which will be constantly varying because of orbital movement, translatory movement, and rotation of the target about its own axes. In effect, then, the size of the retinal image will be the only available visual cue to distance of a target, which means that the real size of the target must be known to the observer. Furthermore, there is reason to believe that dependence upon this cue, as such, is rather slight in ordinary viewing situations, which implies that accuracy of distance judgments based on retinal size alone should be rather poor.

There are other factors which will contribute to poor accuracy of distance judgment in space. The absence of shadow gradients a the fact that sunlight is collimated (parallel rays) will tend to make objects at distances greater than the effective range of binocular cues have a two-dimensional appearance. Also, since most man-made objects will be fairly shiny, there will be other brightness gradients (e.g., a specular "hot-spot" surrounded by decreasing brightness) which may provide confusing cues. Rotation of the target about its own axes may provide still other sources of confusion. Since only those parts of the target directly illuminated may be visible at all, there could appear to be continuous changes in the apparent size of the target which are independent of distance.

Several studies have sought to determine the degree to which the observer's visual capability is degraded under space conditions. Arnoult, McKinney, and Adams (1962) presented *Ss* with an illuminated disk at various distances in a completely darkened area. Results indicated that average errors in distance judgment exceeded 32 percent; individual ranges varied from 3 to 247 percent. There also existed a substantial amount of inter-subject and inter-judgment variability.

Pennington and Brissenden (1963) asked *Ss* to estimate the distance of targets of known size at randomly selected distances; they found that estimates were highly consistent, with a high degree of accuracy being observed for distances under 500 feet. Small objects tended to produce underestimations, whereas overestimations were more frequent for large objects.

Beasley and Pennington (1965) conducted a series of tests in order to determine the human ability to judge range with no cues except the apparent size of the object viewed. The results showed that _Ss_ tended to overestimate the range of the larger models; furthermore, the _Ss_ accurately estimated the range of receding targets at much greater distances than that of approaching targets. The authors stated that it is possible that the point at which the size and shape of a specified target can first be resolved could determine the specific distance on which subsequent estimates could be based.

An experiment by Koppa (1965) has indicated that accuracy of distance judgments, under simulated space conditions, diminishes as a function of target distance both with and without a star field patterned background; however, the presence of the star field appears to produce more accurate and less variable estimations at nearer distances (200 ft.). Mean observer estimation error ranged from 95 to 955 feet. The author suggested, on the basis of a high degree of within-observer consistency, that anchoring procedures involving a standard distance may improve performance.

The present studies were intended to assess the accuracy of verbal absolute distance judgments under simulated space conditions, with no information other than the actual size of the target. These two experiments attempted to specify the ways in which the accuracy of distance estimates may be improved; specifically, the effects of standard verbal anchors and sequential presentation of stimulus distances (as opposed to randomly presented stimuli) were evaluated.

EXPERIMENT I

Method

Subjects.--Twenty male undergraduates at Texas Christian University were paid to participate in this research. All observers possessed emmetropic (uncorrected) vision as judged by an optometrist. None of the observers had experience in similar research, and they were not informed of the intent of the research until the conclusion of the study.

Apparatus.--Apparent distances were generated by an opto-mechanical simulator. The device offered a high-fidelity, three-dimensional image of a 30 x 13 ft. (9.14 x 3.96 m.) space vehicle (Apollo Command and Service Module) illuminated by a "sun" source in a star-free, outer-space environment. The light was maintained at a fixed distance from the target, insuring that the apparent brightness varied appropriately with simulated distance. Furthermore, the apprent source of the reflected light rays was appropriate to the distance being simulated. The usable distance range was 150 ft. to 20,000 ft. (45.72 m. to 6096 m.). The target was tilted approximately 37° toward the observer, such that the maximum simulated vertical dimension was about 27.34 ft. (8.33 m.). The apparatus is described in detail by Arnoult, Vincent, Brown, and Hensleigh.[1]

Orientation.--Each S participated initially in an orientation session, during which he was instructed to estimate the distance of the target at 40 separate distances within a range from 200 ft. (60.96 m.) to 5000 ft. (1524 m.).

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[1] M. D. Arnoult, R. J. Vincent, B. R. Brown, and R. H. Hensleigh, Description of the NASA-TCU Space Vision Simulator. Contract Report, Project NAS 2-1481 (in progress).

All _S_s were presented with these stimulus distances in the same order. A shutter occluded the scene while the target was moved from one position to another. Responses were reported in feet by 15 _S_s, in yards by 4 _S_s, and in the metric system by a single observer. At no time was any observer informed of the accuracy of his responses during the orientation session. Care was taken to insure that the _S_s were unaware of the way in which the simulation was accomplished. The average elapsed time between judgments was 10 seconds.

The only information provided the observers during the orientation session was the size of the target. In an attempt to relate the target dimensions to familiar objects, each _S_ was permitted to inspect two adjacent rooms within the laboratory, the overall dimensions of which were 30 x 12 x 10 ft. (9.14 x 3.66 x 3.05 m.). He was informed that the target would just about fit into that structure.

On the basis of the responses in the orientation phase, the _S_s were rank-ordered as "over- or underestimators". Each _S_ was then assigned to one of four experimental groups such that the five observers in any one group were matched on the basis of their earlier performance with _S_s in the other groups.

Stimulus distances.--Twenty equally spaced distances between 200 ft. and 960 ft. (60.96 m. and 292.61 m.) (40 ft. increments) or 20 equally spaced distances between 1000 ft. and 4800 ft. (304.80 m. and 1463.04 m.) (200 ft. increments) were presented twice in irregular order each day. All _S_s were presented with the same 40 distances in the same order under a given condition. Only one stimulus range was presented per session.

__Procedure__.--The _Ss_ in the four experimental groups each made observations under four experimental conditions. The order of conditions was different for each group.

In those conditions referred to as anchor conditions (A) the _Ss_ were told the exact simulated distances of the end points of the stimulus range prior to the 1st, 11th, 21st, and the 31st stimulus presentations. The _Ss_ viewed the target as this information was provided.

During the sessions comprising the no-anchor conditions (NA) the observers were shown the most extreme stimuli prior to trials 1, 11, 21, and 31, but they were told only that no stimulus would be presented nearer (or farther) than these distances. The apparent distances of these stimuli were not divulged. Table I depicts the experimental design.

TABLE I
ORDER OF PARTICIPATION IN VARIOUS EXPERIMENTAL CONDITIONS FOR EACH EXPERIMENTAL GROUP

Group	Verbal Anchor (A)		No Verbal Anchor (NA)	
	Short Range	Long Range	Short Range	Long Range
A	4	3	1	2
B	3	4	2	1
C	1	2	4	3
D	2	1	3	4

Results

For the graphical analyses reported below, distance judgments under all conditions from all Ss were converted to a percent error score. Percent error as used here is the ratio

$$\frac{\text{Judged Distance} - \text{Simulated Distance}}{\text{Simulated Distance}}$$

Except where noted, only the absolute value of the percent error score was considered for analysis. In all analyses the median was used as a summary statistic for the percent error scores.

Blocks of trials (Fig. 1).--Group median percent errors for each experimental condition were plotted in blocks of 10 trials. Inspection of Fig. 1 reveals the following trends: (1) verbal anchors for both long and short ranges produced a large drop in median percent error; (2) as expected, judgments for the orientation session were the least accurate; and (3) for the orientation and no anchor conditions, there was some improvement in performance over blocks of trials; such improvement was not exhibited under the anchor conditions.

Grouped data (Fig. 2).--Distance judgments, in terms of median percent error, for the various experimental conditions were plotted as a function of the condition administered during the first session of the experiment. Inspection of Fig. 2 shows that the presence of anchor information tended to increase the accuracy of distance estimates; furthermore, the "anchor first" condition led to improvement only under the NA conditions (for both ranges).

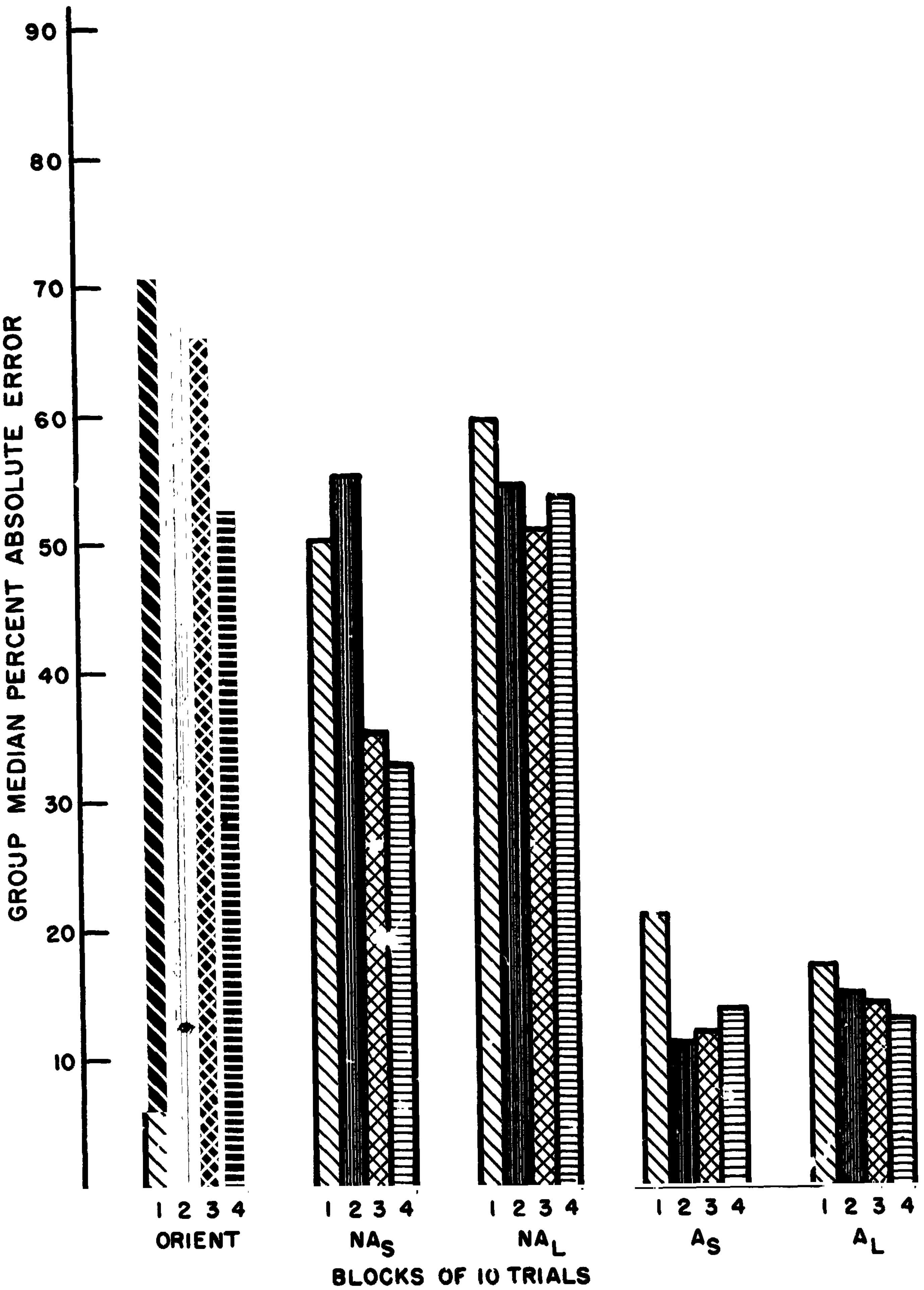

Figure 1. Median percent error in distance judgments. Group data showing median percent error (absolute value) for each block of ten trials for each experimental condition and the orientation session.

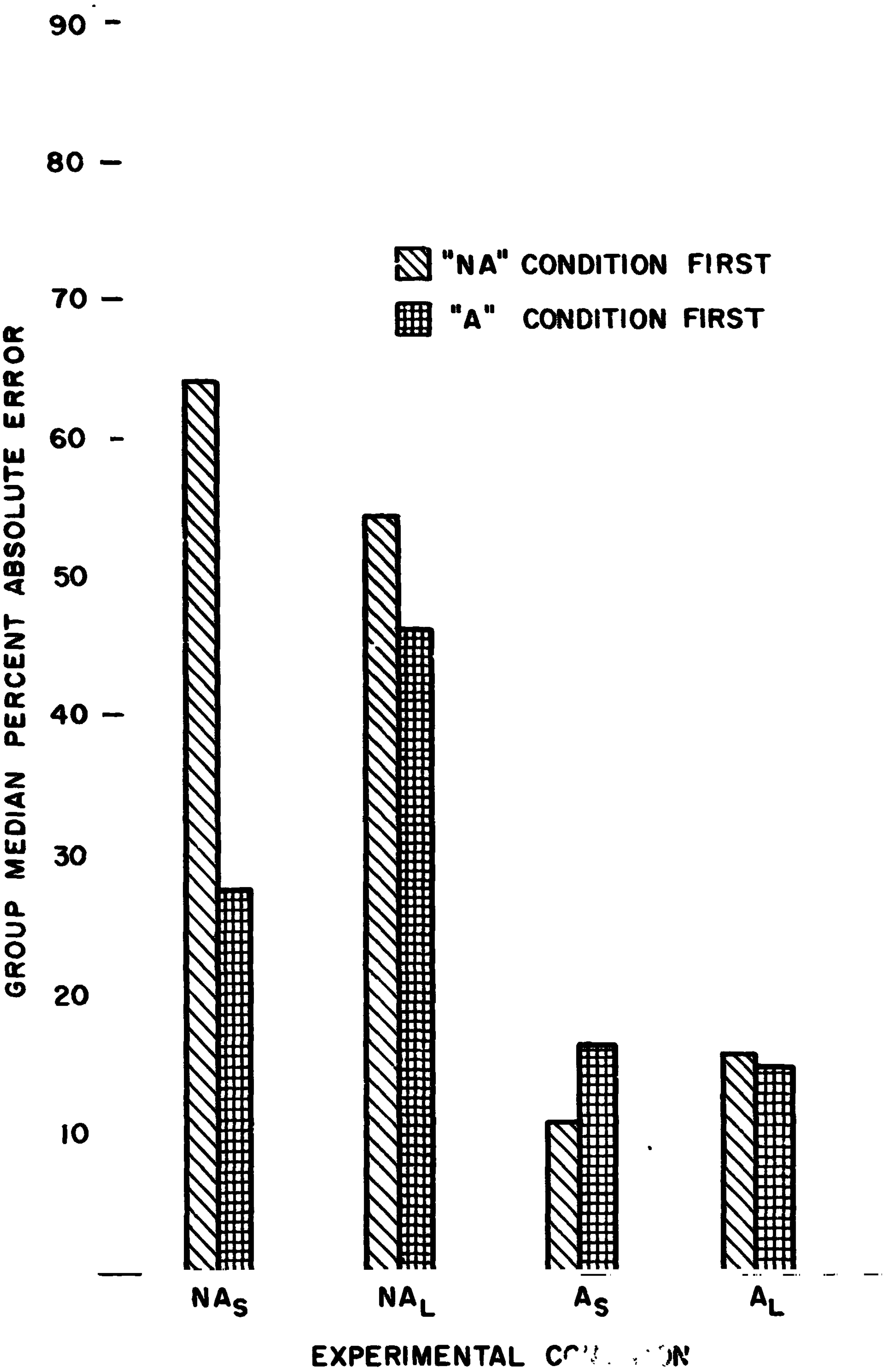

Figure 2. Group median perce[illegible] e[illegible] [illegible]ance judgments. Data for each experimental condition broken [illegible] [illegible]egories on the basis of the presence or absence of anchor inform[illegible] [illegible]s first trials.

Specific distances--No anchor condition(Figs. 3 & 4)[2].--The median percent error scores for the NA conditions were plotted as a function of indiviidual distance points. Inspection of Fig. 3 (short range) and Fig. 4 (long range) reveals the following general trends: (1) accuracy of judgments varied widely among the individual distance stimuli; (2) for the short range, accuracy of distance estimates increased as a function of increasing the number of previous sessions; and (3) the number of previous sessions was irrelevant to performance for the long range.

Specific distances--Anchor condition (Figs. 5 & 6).--Median percent error scores for the verbal anchor conditions were plotted as a function of individual distance points. Inspection of Fig. 5 (short range) and Fig. 6 (long range) shows the following trends: (1) for both long and short ranges, the presence of anchors produced a large improvement in performance as compared to the no anchor conditions (Figs. 3 & 4); (2) accuracy of judgment for the individual distances was relatively constant; (3) percent error among distance points varied most for the long range; and (4) the number of previous sessions had little effect on performance under the anchor condition.

Over- and underestimations (Fig. 7).--For this analysis responses were dichotomized as over- and underestimations on the basis of the direction of the error in judgment. Figure 7 shows performance of over- and underestimators (O or U) in the A and NA conditions. The four experimental groups were

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[2]Technically, Figs. 3 & 4 and all subsequent figures should be constructed as bar graphs as was Fig. 1. The authors feel however that the information in the data can be most clearly communicated by plots in the form of Figs. 3 & 4.

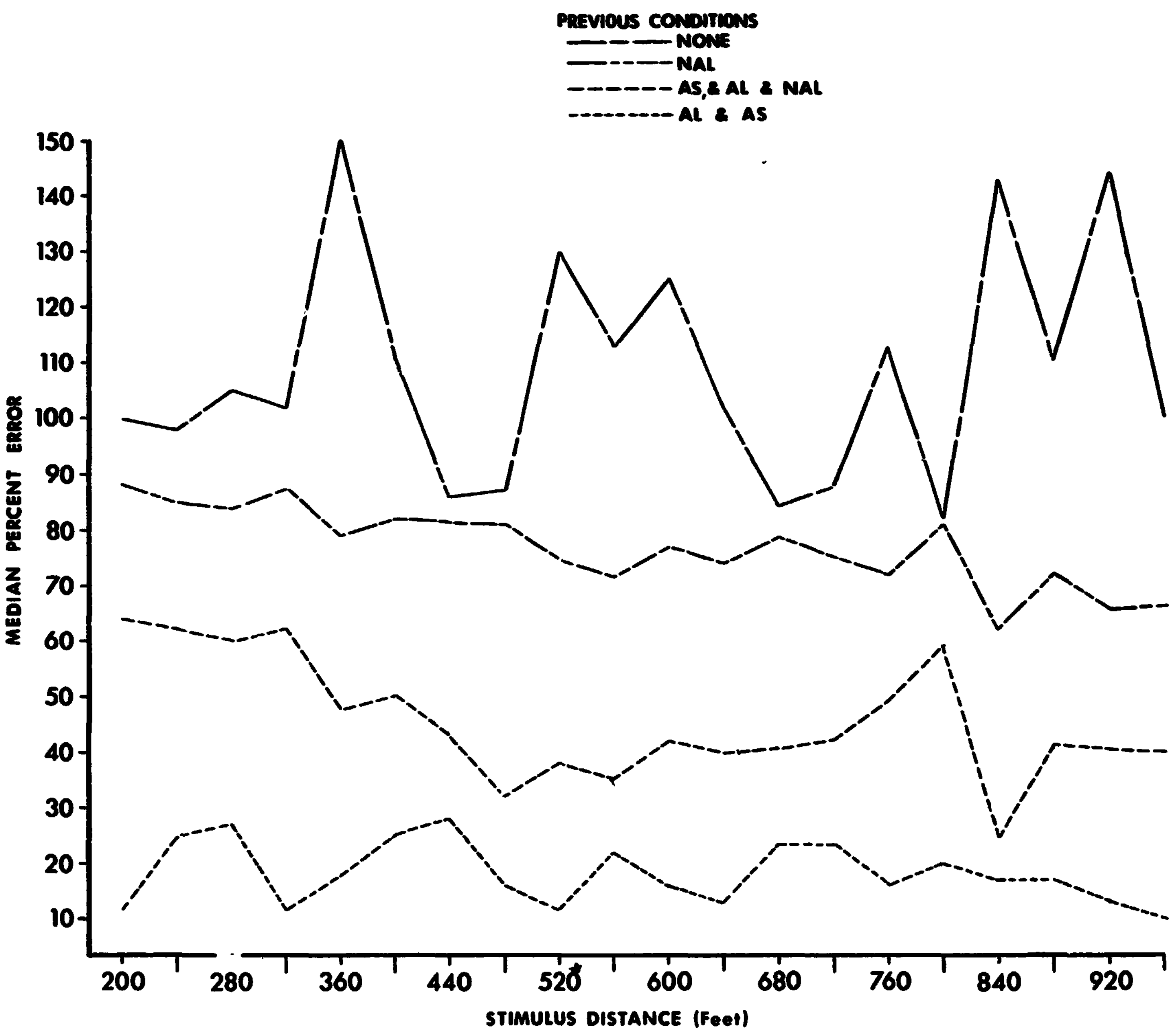

Figure 3. Random Presentation, Short Range, No Anchor Condition (NA_S).

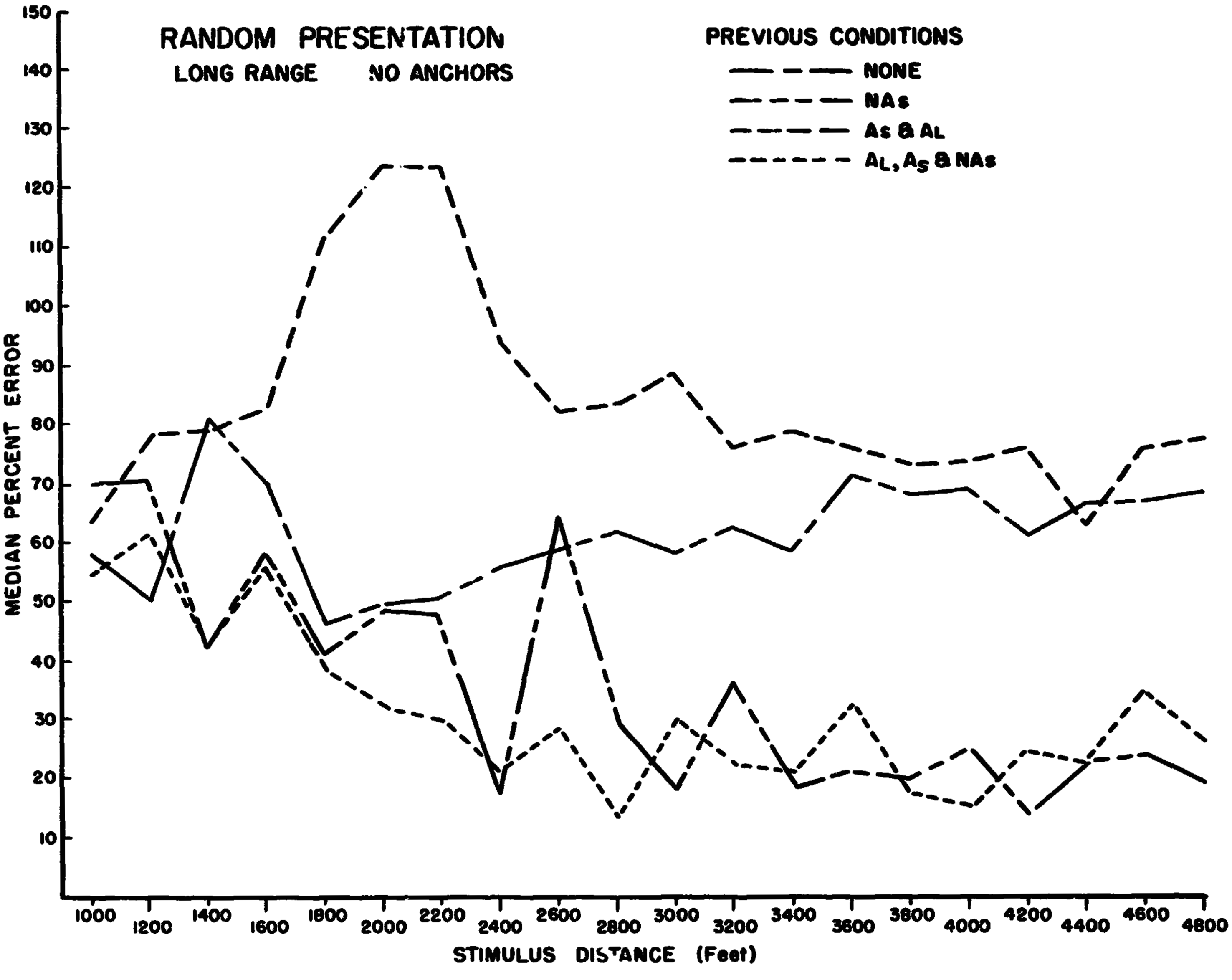

Figure 4. Median percent error in distance judgment for the NA_L condition.

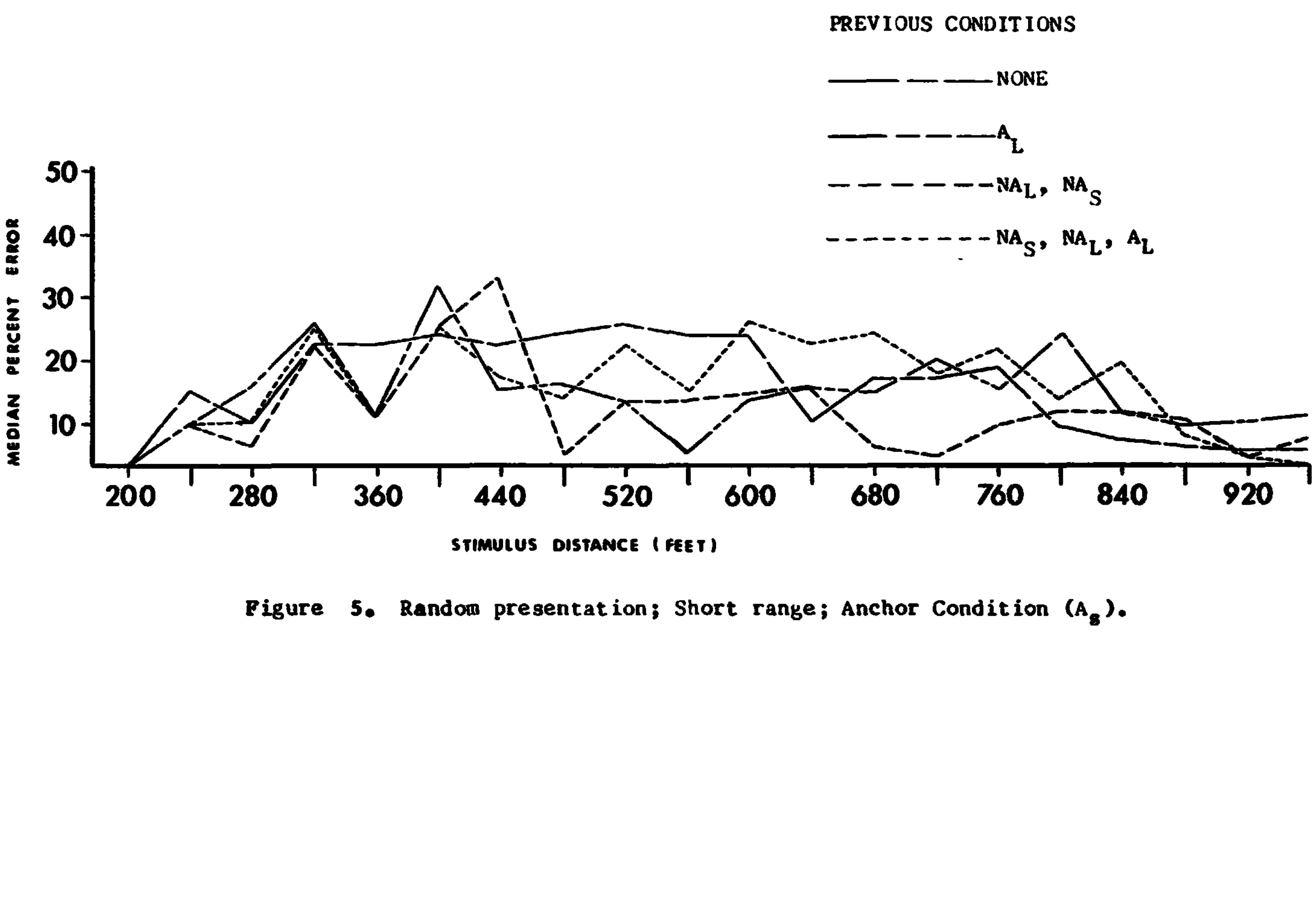

Figure 5. Random presentation; Short range; Anchor Condition (A_s).

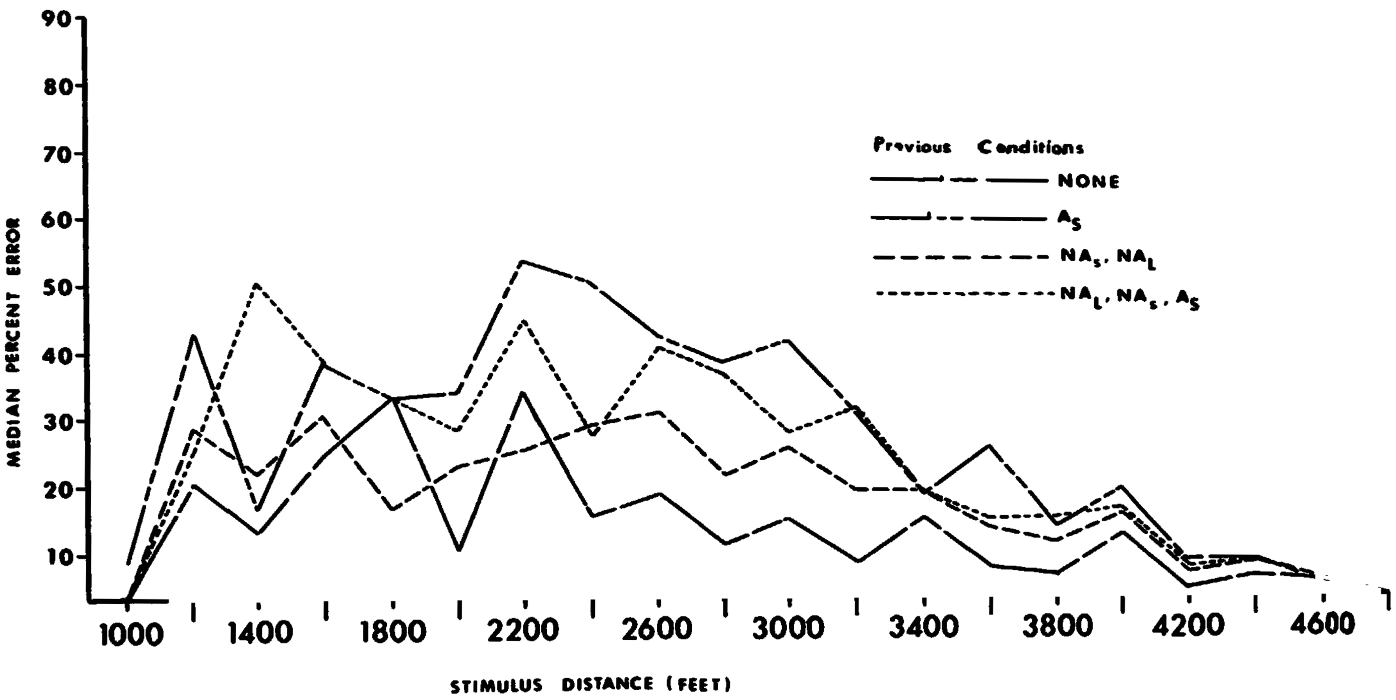

FIGURE 6. Random Presentation; Long Range; Anchor Condition (A_L).

combined into 2 groups: those Ss receiving NA instructions in their first session and those receiving A instructions in their first session. The range factor was collapsed in this analysis.

Inspection of Fig. 7 shows that, regardless of the amount of previous experience, performance under the A conditions was facilitated. For NA sessions, presentation of anchors in the first experimental session produced some improvement as compared to the NA first condition. For the sessions involving anchors, the presence of anchors or no anchors in the first session was irrelevant to performance. Contrary to expectation, there were no consistent results concerning the over- and underestimations.

Discussion

As expected, the accuracy of verbal distance judgments was drastically improved by the availability of anchor information. Although such standards tended to decrease within-subject variability, there nevertheless remained a substantial amount of variability between observers. It is likely that Ss varied greatly in their ability to retain and effectively utilize anchor information over an extended period of time. In general, the judgments made under NA conditions were facilitated by having received anchors in a previous session; however, such improvement was not as large as that observed in sessions conducted under anchor conditions. It thus appears that the availability of standards in a particular session was entirely sufficient regardless of the previous experience of the observers.

Verbal judgments of distance were highly inaccurate when anchor information was not made available to the observers; both within- and between-observer variability was quite large. Under these NA conditions, extended practice with

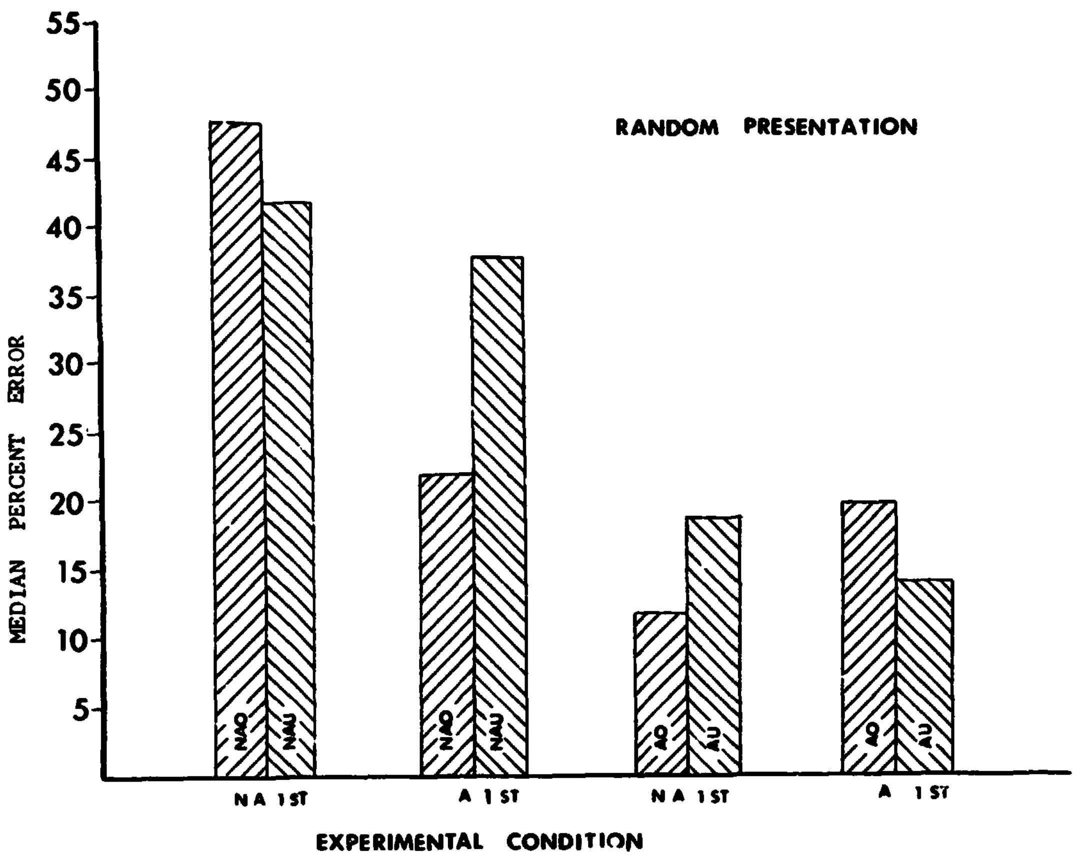

Figure 7. Over- and underestimations. Random presentation. Data categorized on the basis of the condition in which the error occurred and the condition in which each S first participated. The range variable was not considered for this analysis.

the stimuli of a given range resulted in little improvement in performance. The Ss might have been unable, in the absence of standards, to label adequately the various distances. The use of fractional distance judgments (e.g., half-distance judgments) which involve no verbal response by the Ss should help distinguish between errors based on distance "naming" and errors which are due to an inability to behave appropriately with respect to the distant stimuli. Although distance range is likely a main determiner of over- and under-estimations, the large performance variability in this experiment obscured any meaningful trends involving these types of errors. Extreme caution must be taken in attributing any significance to performance differences under such circumstances.

It is probable that the irregular presentation of the distance stimuli in this experiment was quite unlike most situations encountered by the Ss in the real world. The distance estimate requirements imposed by the environment usually are of a sequential nature; consequently, the high within-observer variability may be reduced by presenting the distance stimuli in ascending or descending order of magnitude.

EXPERIMENT II

Method

Subjects.--Sixteen male undergraduates at Texas Christian University were paid to participate in this study. Eight of these Ss were sophisticated observers since they had participated in the previous experiment. The remaining eight Ss were naive as to the intent of the research. All Ss possessed emmetropic (uncorrected) vision as judged by an optometrist.

Procedure.--This study was identical to Experiment I in all respects except for the following procedures: (1) two new sets of ten distance stimuli each were selected at random from each of the same distance ranges used in the first experiment; (2) the stimulus distances were presented to Ss in ascending or descending order of magnitude; (3) the presentation of the various sets of stimuli were counterbalanced within the two distance ranges, as well as within the anchor conditions; and (4) the naive and sophisticated Ss were assigned to the various experimental groups with the constraint that an equal number of observers from each subject group would appear in each experimental group.

Results

Short range--No anchors (Figs. 8 & 9)*.--The median percent error scores for this condition were plotted as a function of individual distance points. Inspection of Fig. 8 (naive group) and Fig. 9 (sophisticated group) reveals the following trends: (1) in general, accuracy of distance judgments improved as a function of having previously received anchor information, especially for the naive group; (2) accuracy of judgments varied irregularly as a function of

*Refer to footnote 2, page 11.

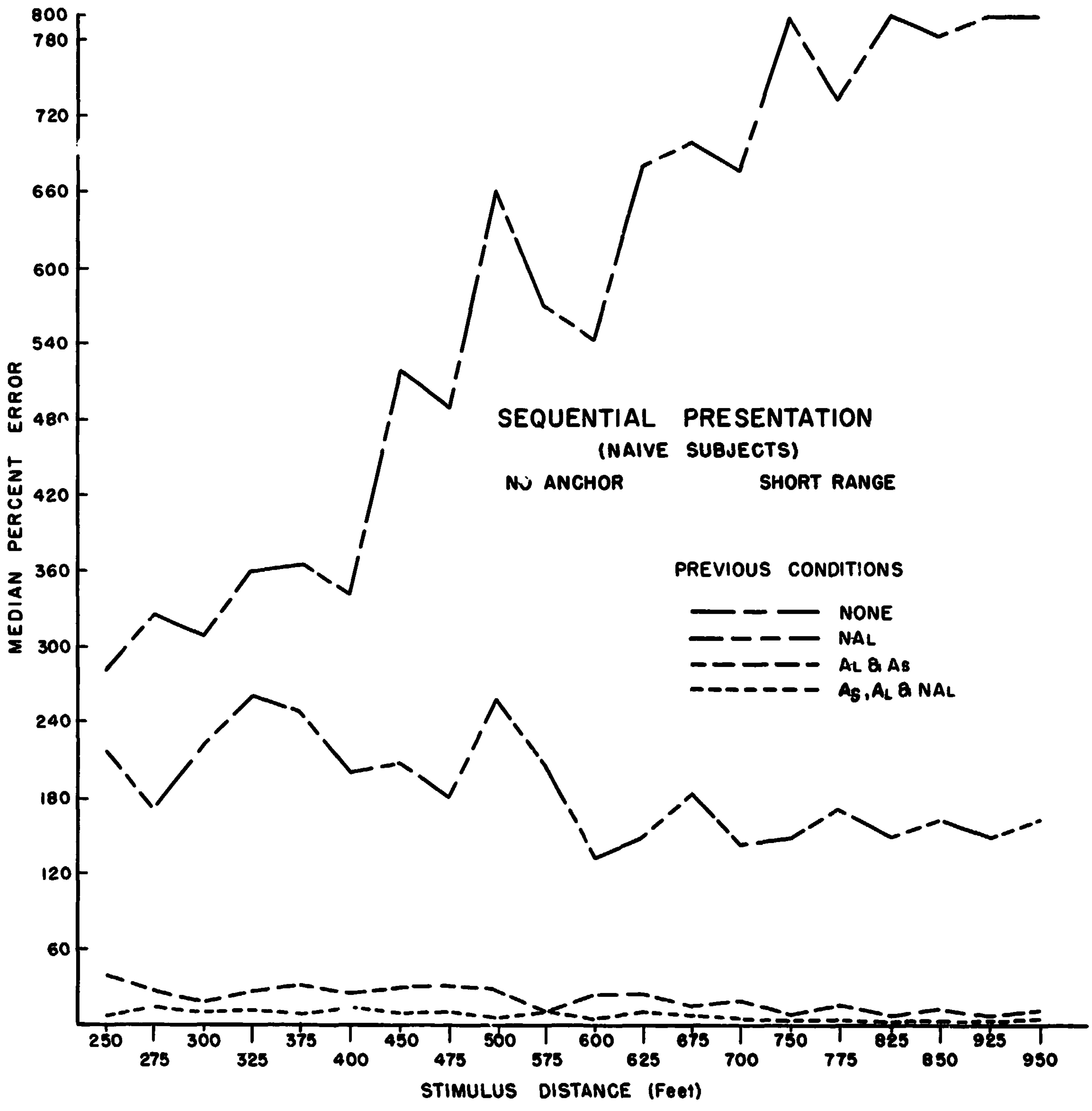

Figure 8. Median percent error in distance judgments. Sequential presentation, naive Ss, NA_S condition.

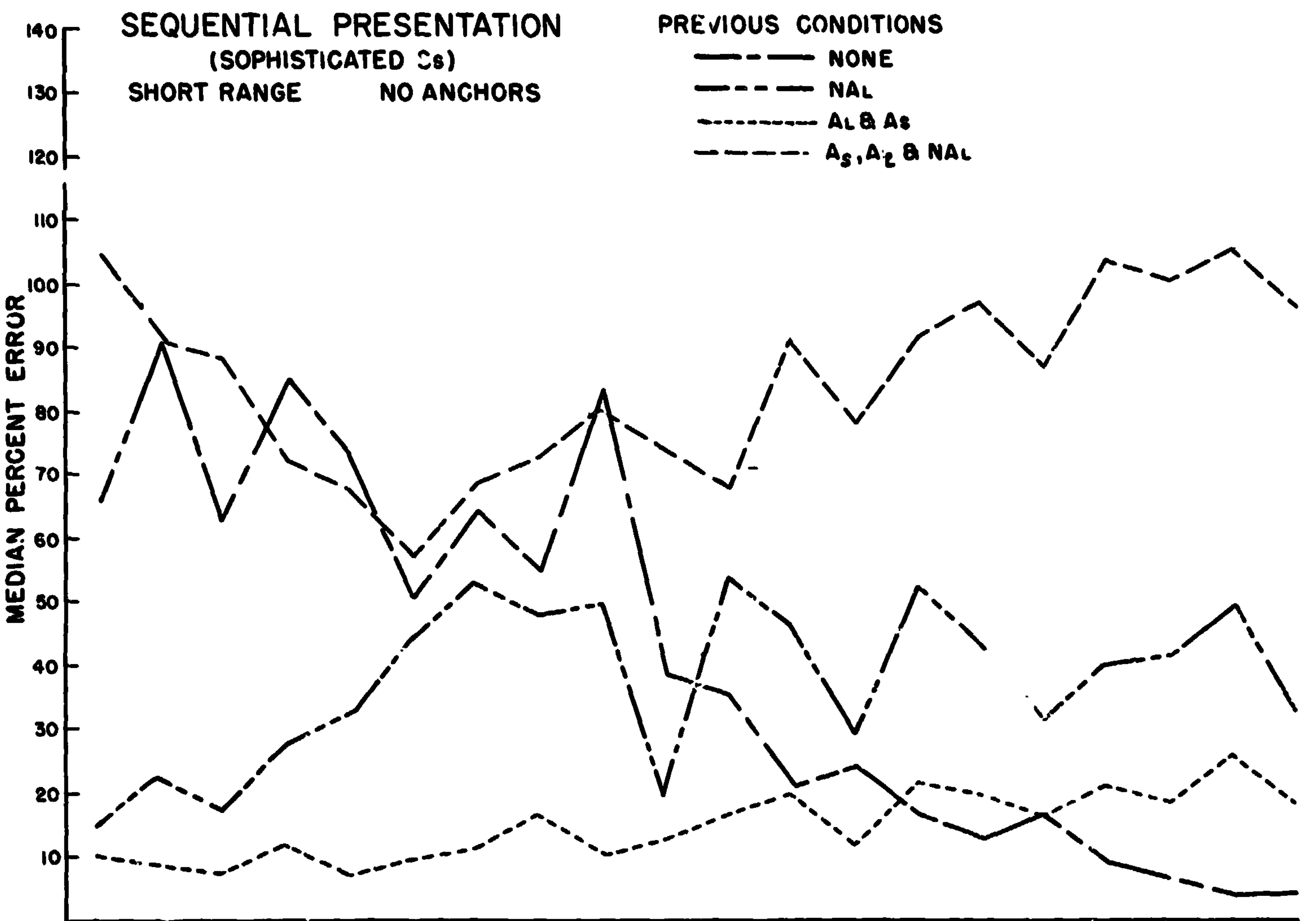

Figure 9. Median percent error in distance judgment. Sequential presentation, sophisticated Ss, NA_S condition.

individual distance points; (3) variability was less for groups having previously received anchor information; (4) the sophisticated _S_s were more accurate for all conditions, although the difference between the two observer groups diminished when anchor information had been previously administered.

Long range--No anchors (Figs. 10 & 11).--The median percent error scores for this condition were plotted as a function of individual distance points. Inspection of Fig. 10 (naive group) and Fig. 11 (sophisticated group) shows the following: (1) the sophisticated _S_s demonstrated greater accuracy in judging distance than did the naive group; (2) this performance difference was less for sessions involving previously administered anchor information; (3) the constancy of judgments across stimulus points was increased by previous anchor experience, especially for the naive group.

Anchor condition (Figs. 12--15).--The median percent error scores were again plotted as a function of individual distance points. The following trends were noted: (1) when anchor information was available, there were no performance differences between the naive and sophisticated groups; (2) accuracy of judgments was greatly improved by the presence of anchors; (3) the range of error was approximately the same as exhibited in NA sessions following an A session; (4) the total number of previous sessions had little effect on performance; and (5) accuracy of judgments remained relatively constant across individual distance points.

Over- and underestimations (Figs. 16 & 17).--Inspection of Fig. 16 (naive group) and Fig. 17 (sophisticated group) shows that there were no consistent results concerning the over- and underestimations; these findings agree with the results of the first experiment. The presence of anchors obviously

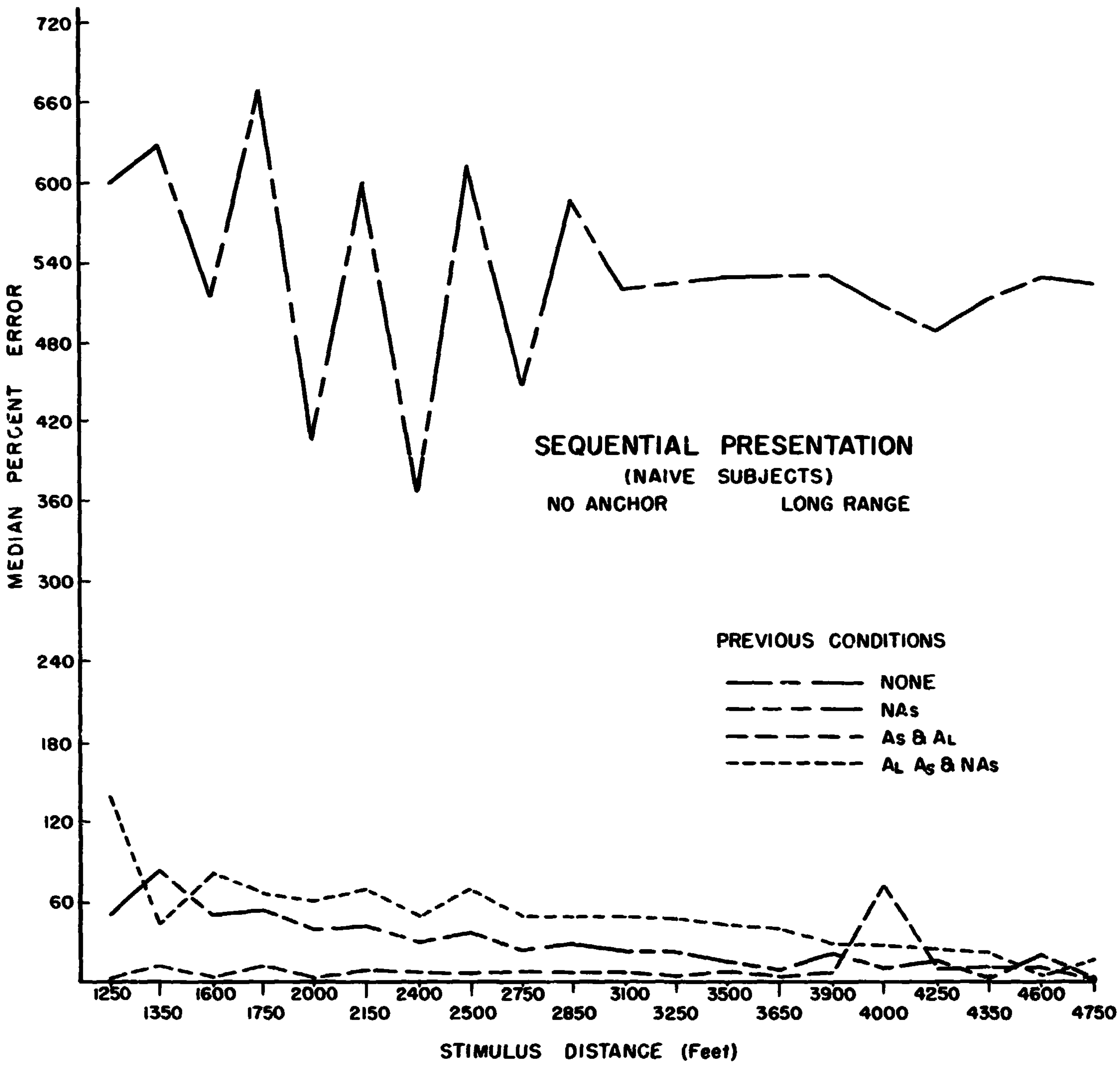

Figure 10. Median percent error in distance judgments. Sequential presentation, naive Ss, NA_L condition.

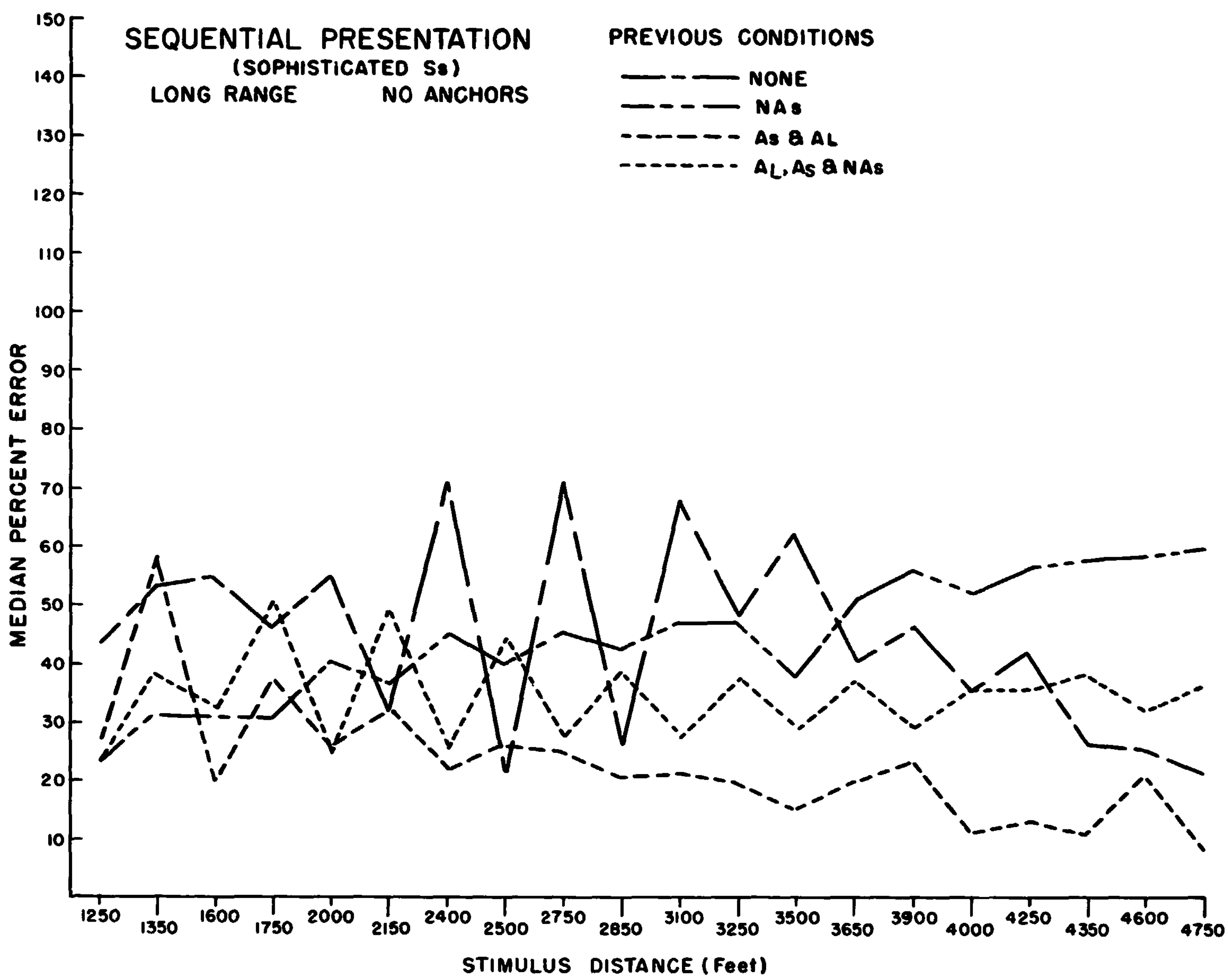

Figure 11. Median percent error in distance judgments. Sequential presentation, sophisticated Ss, NA_L condition.

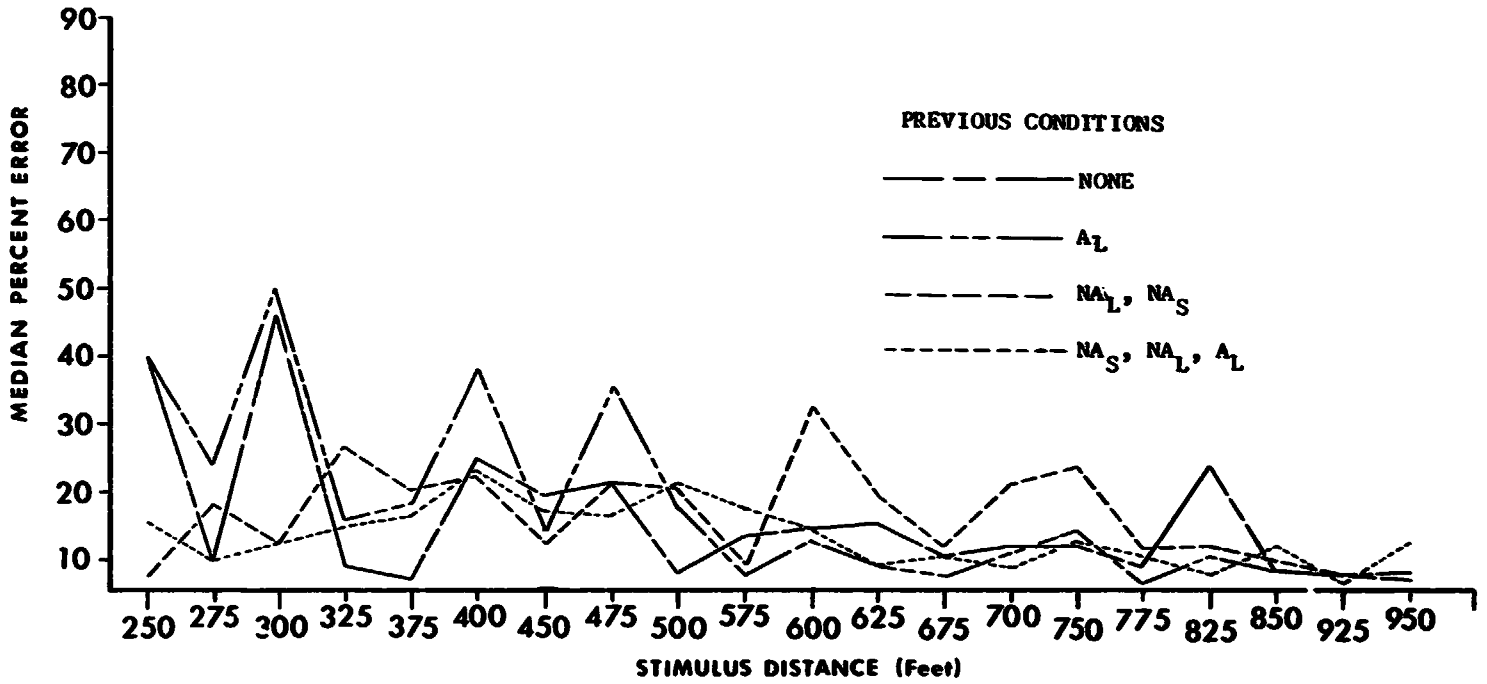

Figure 12. Sequential presentation; Short Range; Anchor Condition (A_S); Naive Ss.

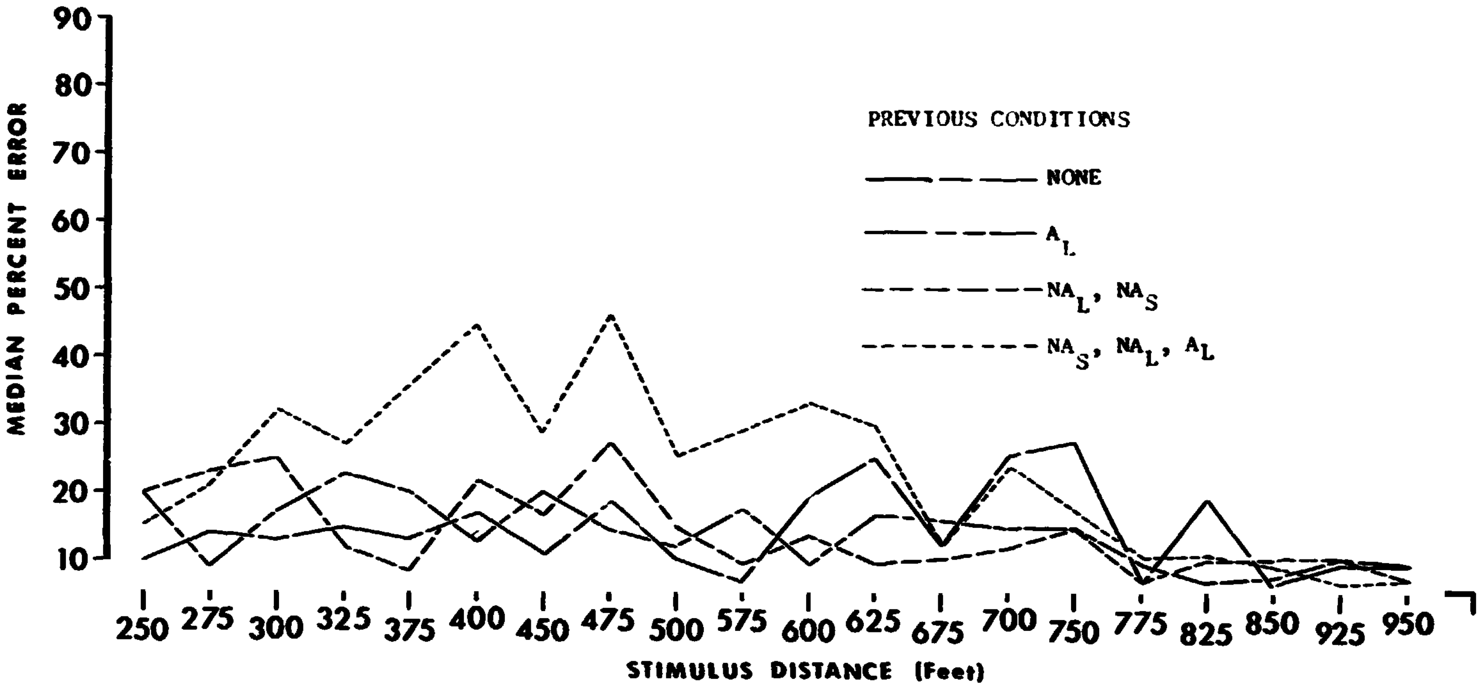

Figure 13. Sequential presentation. Short Range; Anchor Condition; Sophisticated Ss.

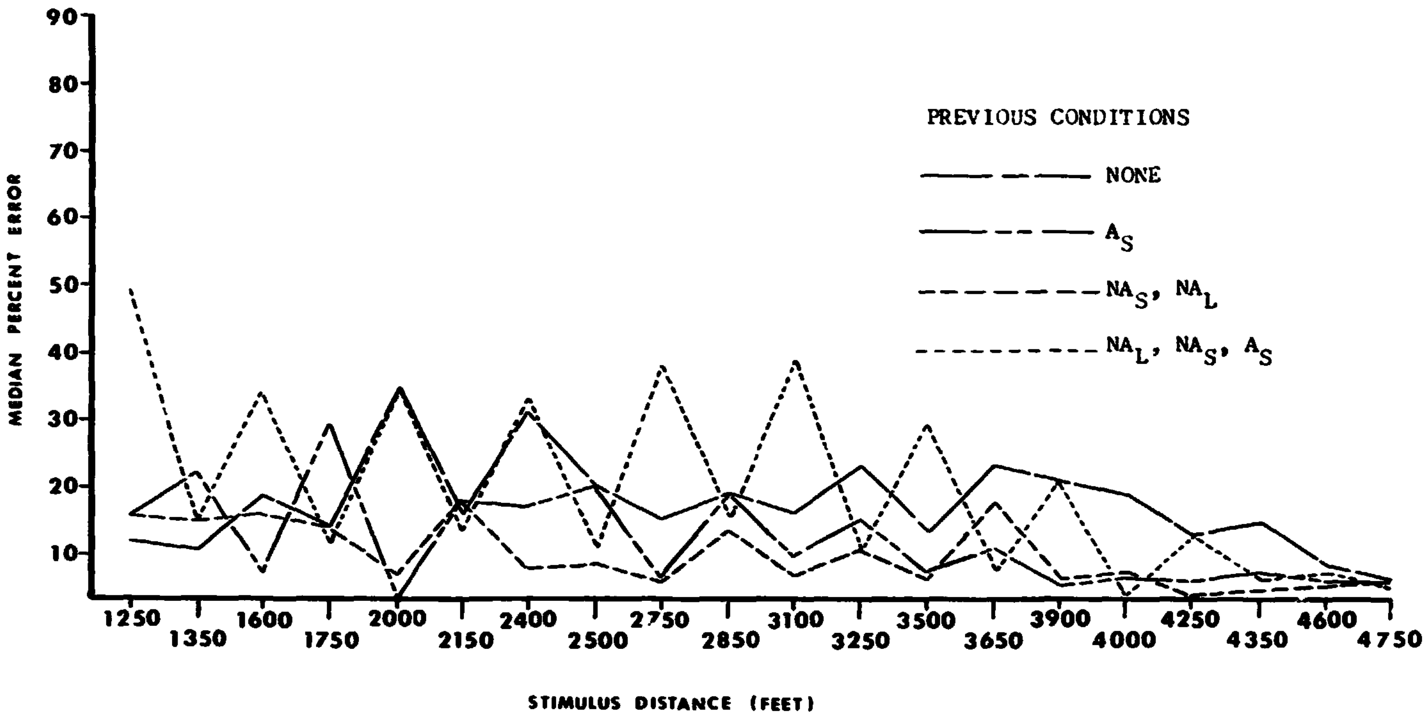

Figure 14. Sequential Presentation; Long Range; Anchor Condition (A_L); Naive Ss.

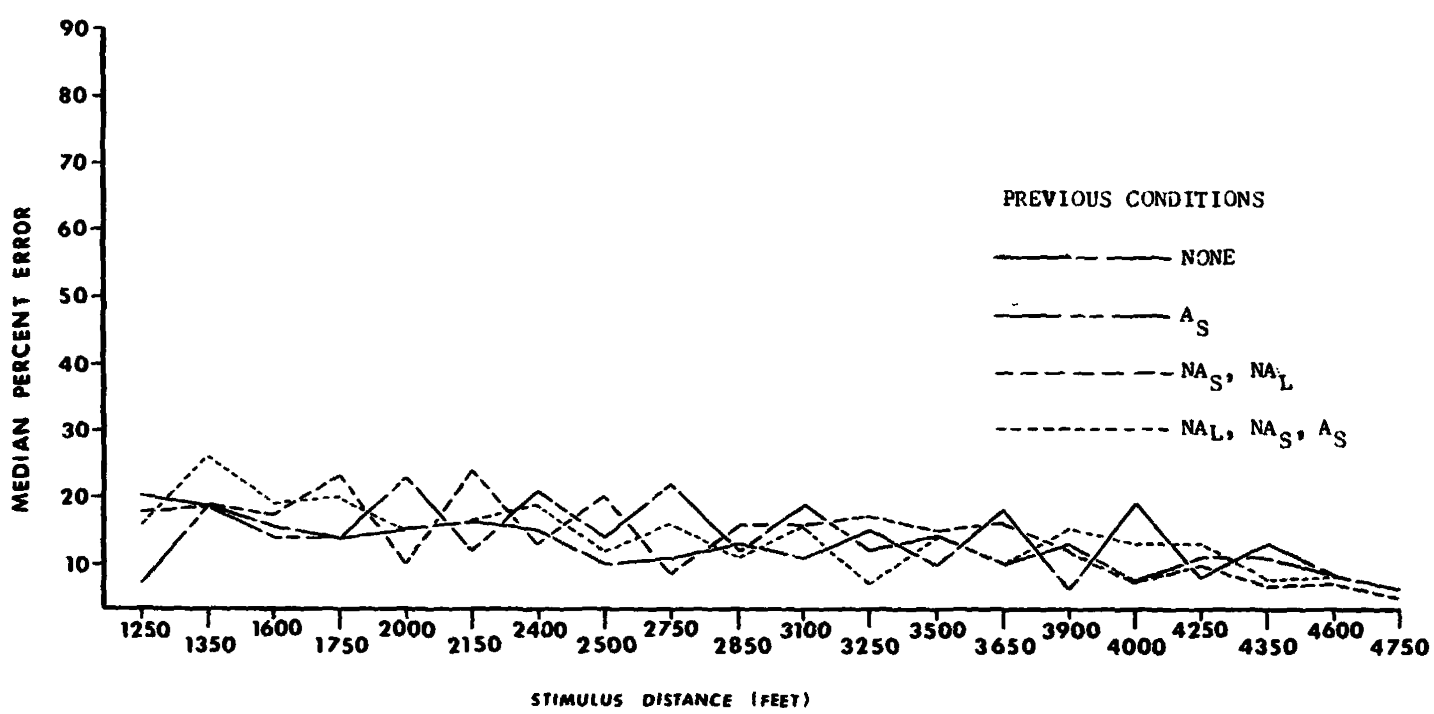

Figure 15. Sequential Presentation; Long Range; Anchor Condition (A_L); Sophisticated Ss.

facilitated distance judgments. However, the "anchor first" condition was equally effective in increasing the accuracy of distance estimates. The naive Ss performed as well as the sophisticated Ss under all NA conditions except the "no anchor first" sessions. Once anchors had been administered, there was little difference between the two groups of observers.

Comparisons of Figs. 7, 16, & 17 indicates that for the A conditions there was little difference between sequential and random stimulus presentation in degree of over- and underestimation. Percent error in NA conditions was generally higher in Experiment I than Experiment II. With the conspicuous exception of the overestimations in the NA first groups, the naive Ss' performance (Fig. 16) was superior to all other Ss in both experiments.

Discussion

As in the first experiment, the availability of anchor information produced greater accuracy of distance estimates; however, the sequential presentation of the distance stimuli reduced the performance differences between the A and NA sessions. It is likely that, since the sequential mode of presentation is more representative of actual environmental conditions than is irregular stimulus presentation, the Ss were able to rely heavily upon past experience. In other words, judgments were more consistent for any given observer, thus reducing somewhat the variability of responses to individual distance points.

Contrary to expectation, there existed little difference in accuracy of judgments between the naive and sophisticated groups. The differences which were observed appeared to be primarily related to the responses made under the NA condition. Apparently, anchors received in previous sessions were as

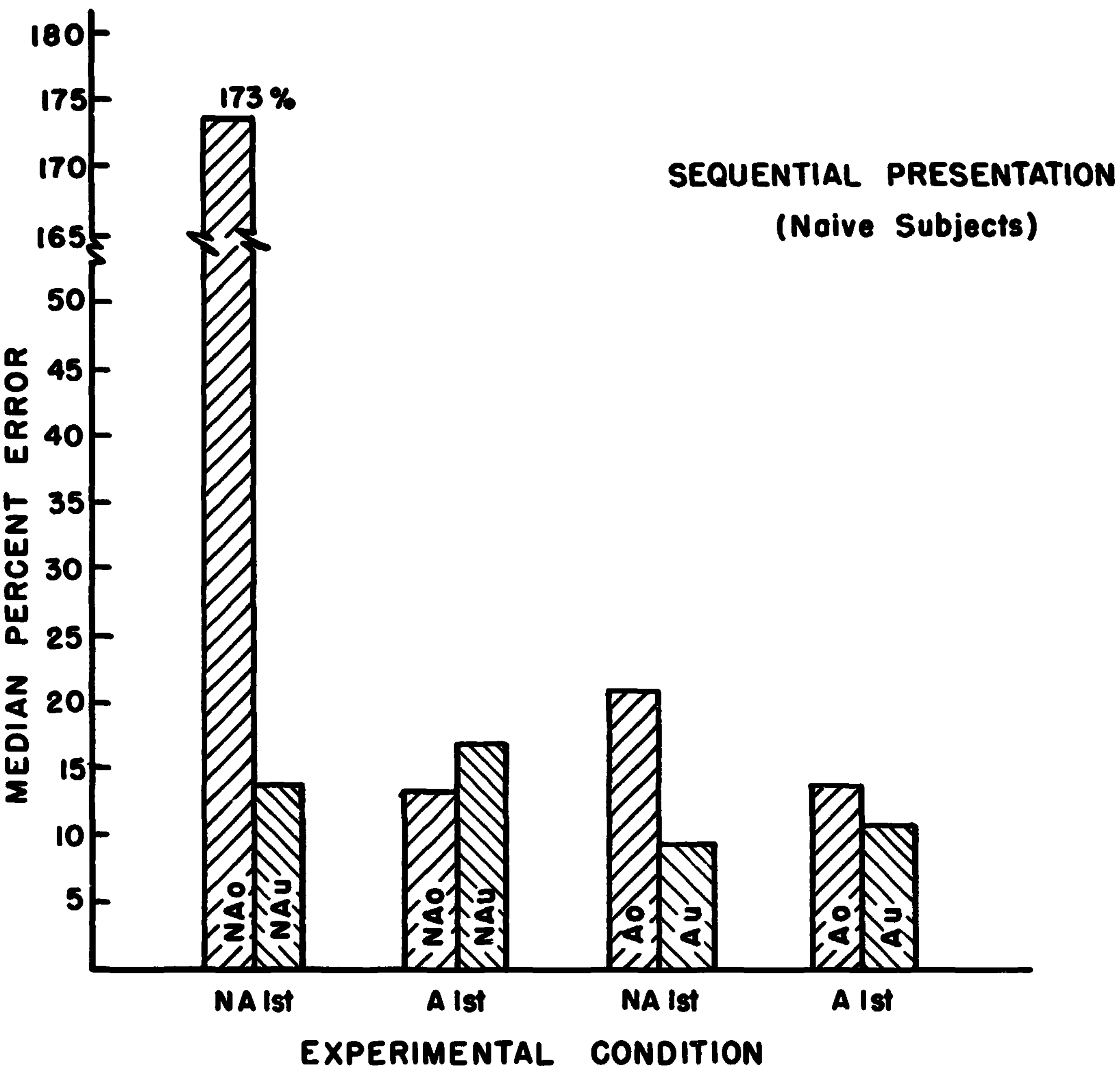

Figure 16. Over- and underestimations. Naive Ss, sequential presentation. Data categorized on the basis of the condition in which the error occurred and the condition in which each S first participated.

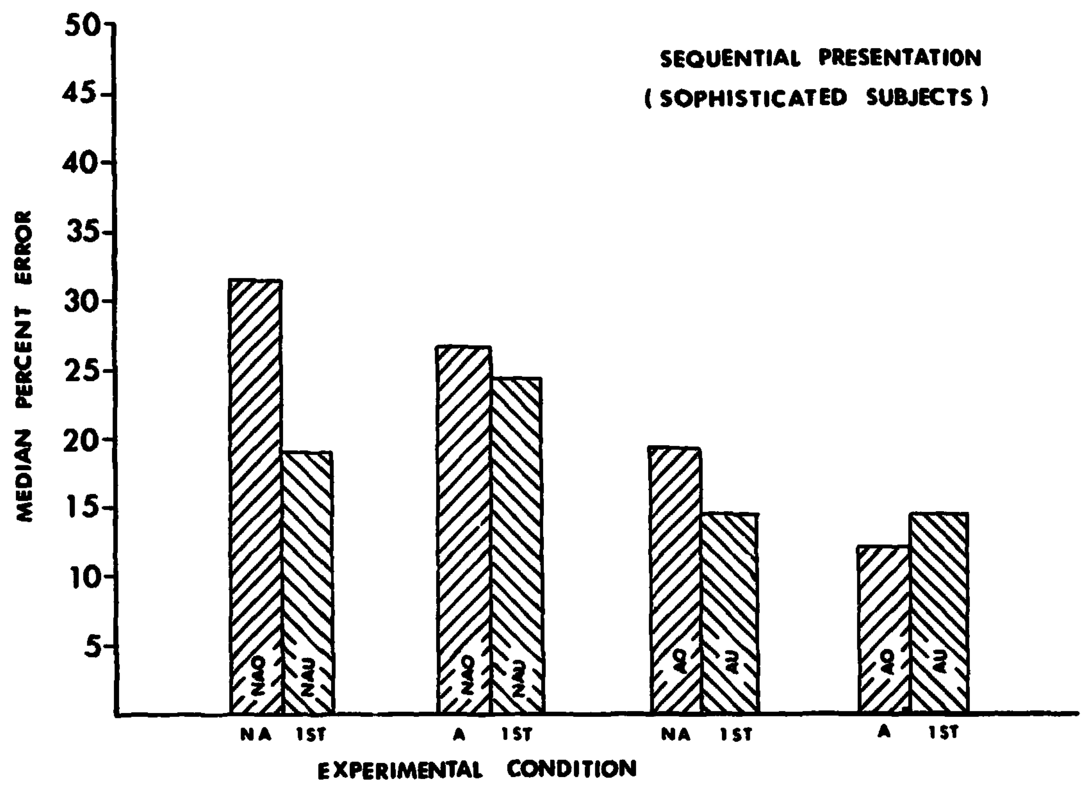

Figure 17. Over- and underestimations. Sophisticated Ss, sequential presentation. Data categorized on the basis of the condition in which the error occurred and the condition in which each S first participated.

effective in reducing error as actual anchor information received in the session being considered. The sequential nature of the **stimulus** presentation may have increased the observers' ability to retain and utilize anchor information over extended periods of time. In fact, the naive Ss performed slightly better than the sophisticated Ss in some cases where anchor information was administered.

Although the sequential presentation of the stimuli undoubtedly facilitated distance judgments to some extent, there remains the problem of distinguishing between "distance naming" and actual judgment difficulties. If performance variability can be reduced by sequential presentation of distance points, it is likely that variability can be reduced even more by methods involving non-verbal responses. Such a situation seems even more analogous to what is required of the observer in the real world.

There remain several problems to be investigated. First, investigation of distance judgments involving nonverbal responses is obviously needed. Second, in order to determine the optimal method for increasing the veridicality of verbal responses, the effects of full and partial knowledge of results should be compared to the effects of anchor information upon performance. Third, since in these experiments size and distance were completely confounded, the effects of varying target size upon distance estimates should be investigated. It is possible that target size determines the degree of over- and underestimations.

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LIBRARY CARD ABSTRACT

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